Appendix D

APPLICATION OF THE NATURAL SYSTEM MODEL TO THE ST. LUCIE WATERSHED

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Contents

List of Figures

List of Tables

Chapter 1

Introduction

Biological[1] investigations of the St Lucie and Caloosahatchee Estuaries lead to an understanding of the relationship between important communities and flow from the watershed. This understanding formed the bases for the salinity envelope concept in which desired minimum and maximum mean monthly flow limits to the estuaries were defined with an "acceptable" number of violations of these limits. The scientific justification for these acceptable violations is weak and therefore needs additional investigations. It has been demonstrated with the optimization model that the amount of retention/detention needed in the watershed to obtain the desired flow to the estuaries is sensitive to the number of acceptable violations allowed, especially the upper violations. Basically, the greater amount of violations allowed, the less retention is needed in the watershed. Therefore, further insights in to the acceptable number of violations may have major influence on the proposed amount of retention needed in the watershed for the St Lucie Estuary. In addition, the effort to establish "Minimum Flows and Levels" for the Estuary is dependent on documenting significant levels of harm of low and high flow. This MFL effort needs to clearly demonstrate the potential impact of flows outside of the salinity envelope. Therefore, it is important to gain a better insight of the "acceptable" violations for several major District concerns dealing with watershed management of the St Lucie Estuary.

Two approaches to gaining a better understanding acceptable number of violations have been suggested, both embracing the need to determine the natural distribution of flows to the estuary. The Pease River has a well defined historical flow record and has minimal impact from development.

[1] The Introduction is adapted from the Draft Scope of Work, Dated 9/10/1998.

Therefore, the distribution of flow from this estuary will be determined and compared with suggested distribution of flows for the St Lucie Estuary. Another method of determining the distribution of flows under natural conditions can be obtained by applying the Natural System Model (NSM) to the St Lucie watershed. The NSM has been used successfully to simulate the predrainage condition in other parts of the District. This report summarizes the application of the NSM to the St Lucie watershed.

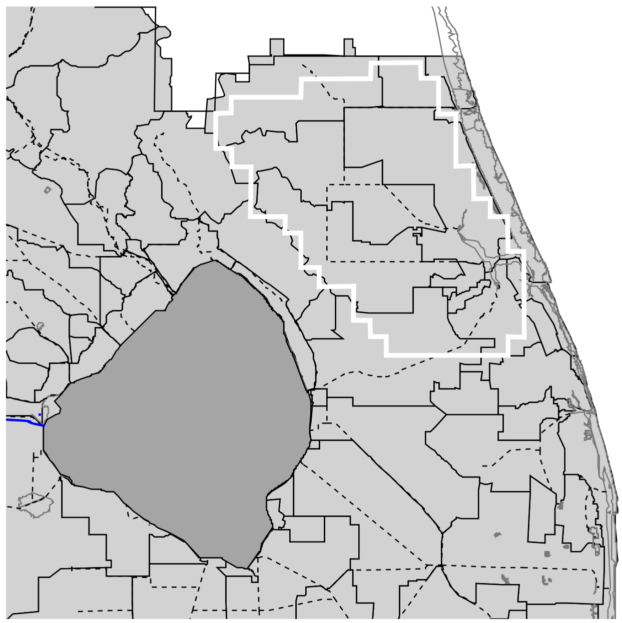
Chapter 2

Model Specifications

The NSM is a two-dimensional coupled surface/ground water model that incorporates the dominate physical process affecting hydrology in south Florida. The model domain is discretized into grid cells, and the spatial properties required to simulate each of the hydrologic processes are estimated for each cell. Spatial properties include vegetation/landscape type, land surface elevation, aquifer depth and permeability, soil storage coefficient and initial water level. Similarly, rivers are discretized into linear segments, and properties associated with each of the rivers are estimated. River properties include river location and dimension, outlet specifications, and coefficients for river to overland flow and river to aquifer interaction.

2.1 Model Domain

The domain of the St Lucie NSM includes the area that under "natural" conditions would have been drained by the St. Lucie River and its tributaries. The St Lucie watershed includes portions of the following surface water management basins: C-44, C-23, C-24, C-25, Tidal St. Lucie, and North Fork St. Lucie River. The model boundary is generally aligned along surface water basin boundaries or in areas where surface water movement is low (Figure 2.1). The principle outlets for excess water are the North and South Forks of the St. Lucie River, which in turn discharge to the St Lucie Estuary.



Notes:
- Surface water management basins delineated by solid black lines.
- Model domain delineated by white line
- Primary canals delineated by dashed lines.

Figure 2.1: Model boundary map.

Table 2.1: Landscape definitions.

No	landscape	Description	% Area
1	mangrove	low coastal areas dominated by mangrove swamps with salt to brackish water marshes	2
2	forested upland	pinelands on higher sands	1
3	marsh	fresh marshes outside the Everglades Basin	3
4	wet prairie	mosaic landscape; sloughs densely filled with grasses; tree islands may be present	35
5	forested wetlands	cypress and hardwood swamps; wetter mosaics of pine flatwoods and depressional wetlands	59

2.2 Vegetation

Cell vegetation type is based on soils information, specifically the Natural Landscape Position coverage. The landscape classification is consistent with definitions contained in the NSM developed for south Florida (Van Zee, 2000). Five landscapes are identified in the St Lucie watershed (Table 2.1).

The St Lucie Watershed lies with the Eastern Flatlands physiographic region. There were many shallow, usually just seasonally wet ponds and long narrow sloughs in these flatlands (Davis, 1943) . The characteristic landscape is either wet prairie or forested wetlands (Figure 2.2).

Model input parameter values for these landscape types are taken directly from the NSM (Version 4.5), whose parameter values are imported directly from the calibrated and verified South Florida Water Management Model (SFWMD, 1999).

2.3 Topography

Land surface elevation is based available GIS topographic coverages for this area. Land surface elevations in the St Lucie watershed range from more than 60.0 ft along the western boundary to less than 4 ft near the St Lucie Estuary (Figure 2.3).

2.4 Surficial Aquifer

Surficial aquifer properties for each cell are defined by aquifer transmissivity and soil storage coefficient values. Transmissivity is the product of

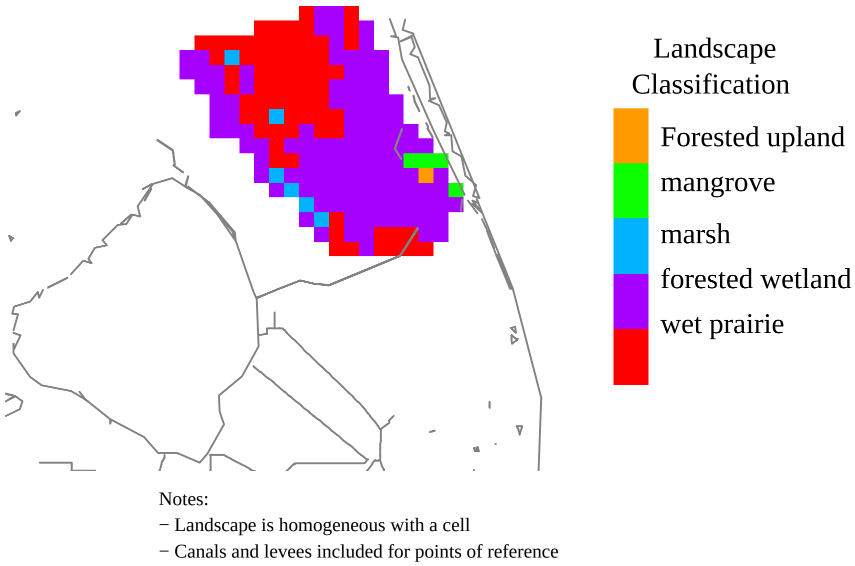


Figure 2.2: Landscape map.

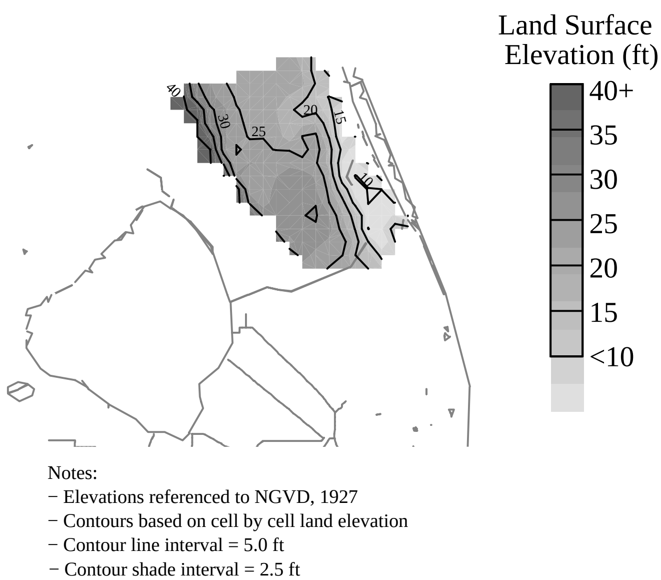


Figure 2.3: Land surface elevation map.

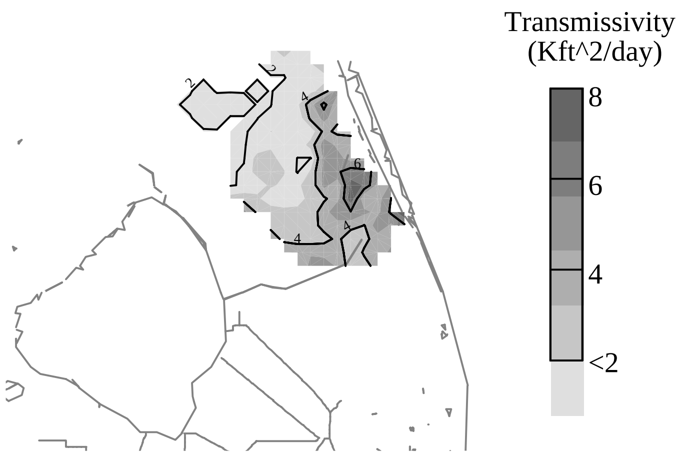


Figure 2.4: Aquifer transmissivity map.

aquifer depth and aquifer permeability, and ranges between 1 Kft$^2/day$ to 8 Kft$^2/day$ (Figure 2.4). Soil storage coefficient is uniformly set to 0.2 ft/ft.

2.5 Rivers

The St Lucie watershed contains rivers and creeks which cannot be represented by the relatively coarse 2X2 mile grid. These surface features are discretized into linear segments, and the impacted cells or river cells, are identified (Figure 2.5). Outflow from a river is discharged to tide or to another river. Although much of the river system in the St Lucie watershed has been excavated, the river location can be approximated from existing hydrography coverages.

2.6 Initial Condition

The initial condition is established in the NSM by setting the initial water level in each cell and in each segment of the rivers. Initial cell water levels are set by uniformly setting the surface water ponding depth in marsh cells

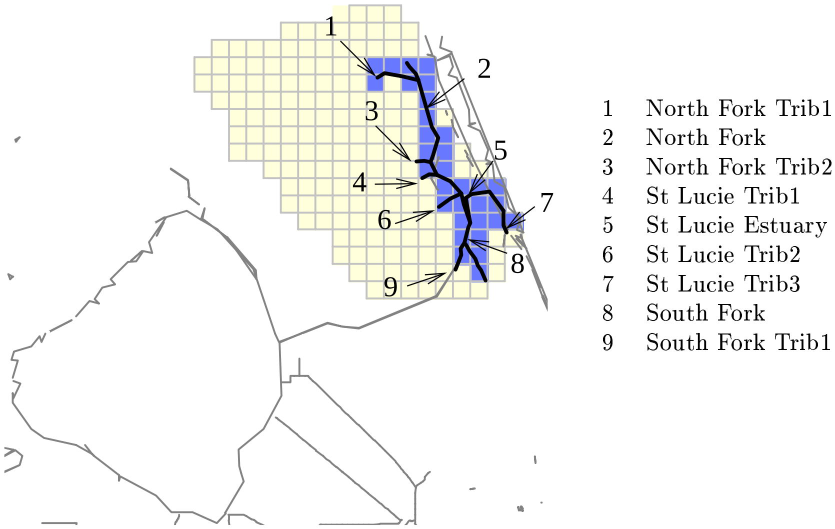


Figure 2.5: Model grid and river location map.

to 0.5 ft, and all other cells to 0.0 ft. The downstream water level for each river is set to the control elevation of the downstream weir. The initial water level in each of the upstream segments are computed, based on downstream level and specified surface water slope.

Chapter 3

Boundary Conditions

Water levels in the model domain fluctuate in response to transient boundary conditions, which are imposed on selected cells. Boundary conditions represent external driving functions which cause water to be added or removed from the model domain. Hydrology in south Florida is primarily driven by rainfall and evapotranspiration (Fennema, et al., 1994). These boundaries are applied on a daily basin to every cell in the model domain.

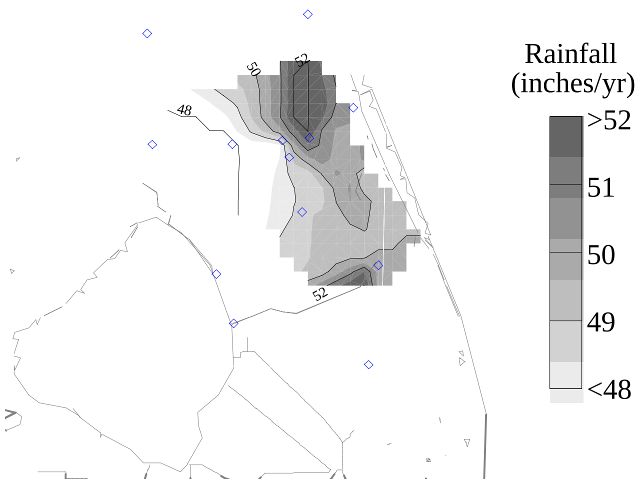
3.1 Rainfall

A rainfall database consisting of 13 stations (Figure 3.1) that reported data during the 1965 - 1997 simulation period. Since data records may not be continuous at each station, daily rainfall for each cell is based on the nearest station with data.

Rainfall in south Florida varies seasonly, with distinct wet and dry seasons. Wet season rainfall results predominately from convective and tropical storms and dry seasons rainfall comes primarily from frontal systems (Sculley, 1986). Rainfall also varies spatially, ranging from less than 47 inches/yr in the extreme western cells to more than 56 inches/yr along the coastal ridge.

3.2 Potential Evapotranspiration

Daily potential evapotranspiration is estimated across the model domain using two station PET stations. PET at Canal Point (located along the eastern edge of Lake Okeechobee) is computed using a modified Penman-Monteith Method. PET at Ft. Pierce station (located in the northeastern region of



Notes:
− 1965 − 1997 simulation period
− Diamond symbols indicate location of rainfall stations
− Contour line interval = 1.0 inches
− Contour shade interval = 0.5 inches
− Canals and levees included for points of reference

Figure 3.1: Average annual rainfall map.

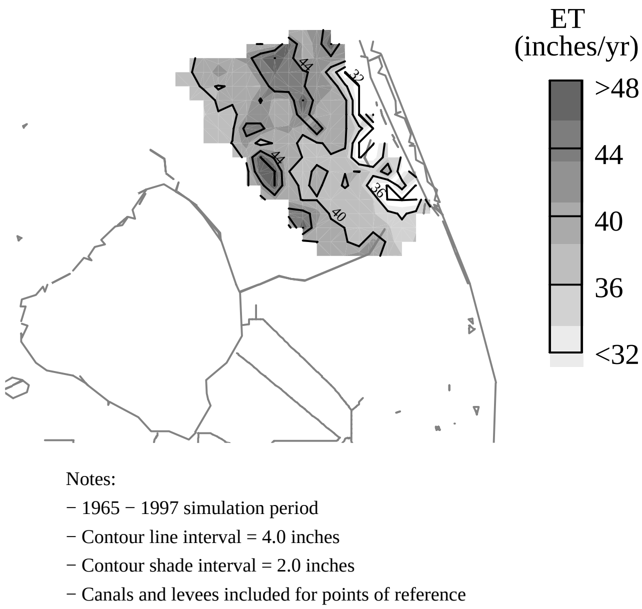


Figure 3.2: Average annual ET map.

the domain) is based on observed pan evaporation data. PET is generally higher at Ft Pierce (63.1 inches/yr) than Canal Point (57.6 inches/yr). PET estimates from two stations are weighted equally to compute the PET at the individual cells.

"Actual" evapotranspiration is computed in the model, and is based on PET and a crop coefficient. Crop coefficients combine the effects of vegetation type, seasonality and water availability. Actual ET ranges from less than 20 inches/yr in the over-drained cells near the South Fork of the St Lucie River to more than 48 inches/yr in the marsh areas to the southwest (Figure 3.2).

Chapter 4

Hydrologic Processes

Water is distributed with the model domain in response to hydrologic processes. Processes are modeled independently within each time step, with more transient phenomena computed before less transient phenomena. River flow is compute first, followed by overland flow, infiltration, evapotranspiration and ground water flow. Rainfall is added to model to the model by increasing surface water depth in each cell at the beginning of a time step. The equations used to represent each of the hydrologic processes will not be presented here (see Van Zee, 2000). However, the relevant parameters for each of the hydrologic processes are presented.

4.1 Infiltration and Evapotransiration

Vertical movement of water within a cell is simulated by infiltration an evapotranspiration processes. Infiltration rates are uniformly set to a very high level, preventing the formation of perched water tables. Evapotranspiration is a function of PET, monthly crop coefficient (Table 4.1 and threshold depths to water table (Table 4.2.

Table 4.1: Monthly evapotranspiration coefficients.

	Month											
landscape	1	2	3	4	5	6	7	8	9	10	11	12
mangrove	.79	.76	.83	.86	.88	.88	.88	.90	.90	.82	.80	.75
upland forest	.74	.72	.77	.77	.78	.78	.81	.82	.82	.76	.77	.75
marsh	.81	.77	.81	.82	.83	.83	.83	.85	.84	.80	.78	.78
wet prairie	.72	.70	.72	.74	.74	.74	.74	.75	.75	.73	.73	.70
wetland forest	.72	.70	.74	.75	.77	.76	.77	.79	.79	.74	.77	.74

Table 4.2: Threshold water depths.

landscape	open water (ft)	shallow root zone (ft)	deep root zone (ft)
mangrove	6.5	0.00	4.0
upland forest	6.0	4.25	10.0
marsh	5.0	0.0	4.5
wet prairie	4.5	0.0	4.5
wetland forest	5.0	0.0	8.0

4.2 Overland Flow

The overland flow process simulates the surface water movement between adjacent cells. The Manning's equation is used to estimate resistance to flow. Parameters for the Manning's equation are presented in Table 4.3. The detention depth is the ponding depth below which there is no overland flow.

Table 4.3: Overland flow parameters.

landscape	Manning's coefficient	Manning's exponent	detention depth
mangrove	0.95	-0.77	0.1
upland forest	0.85	0.0	0.1
marsh	1.15	-0.77	0.1
wet prairie	1.2	-0.77	0.1
wetland forest	0.16	-0.77	0.1

4.3 Ground Water Flow

Ground water flow is simulated by solving for ground water level in a finite difference approximation of flow in unconfined aquifers, using transmissivity values illustrated in Figure 2.4. A zero gradient ground water boundary condition is imposed by establishing "imaginary" cells outside the model domain, adjacent to each boundary cell. These external cells have the same transmissivity and head values as their model domain counterparts.

Table 4.4: River specifications.

		river		weir crest		
		width	slope	elev	width	
no	name	(ft)	(ft)	(ft)	(ft)	outlet
1	North Fork Trib1	1000	4.0	9.0	80	North Fork
2	North Fork	2000	0.0	3.0	320	St Lucie Estuary
3	North Fork Trib2	500	0.0	6.0	80	North Fork
4	St Lucie Trib1	250	0.0	4.0	80	St Lucie Estuary
5	St Lucie Estuary	4000	0.0	2.0	2000	tide
6	St Lucie Trib2	500	1.0	3.0	80	St Lucie Estuary
7	St Lucie Trib3	750	0.0	4.0	160	St Lucie Estuary
8	South Fork	500	2.0	3.0	320	St Lucie Estuary
9	South Fork Trib1	180	2.0	7.0	80	South Fork

4.4 River Flow

The fiver flow process simulates the influence of rivers on water levels in adjacent cells. River cells are identified by the presence of a river segment within the cell (Figure 2.5). Rivers are modeled as storage volumes, based on river length and width, and depth above a downstream weir which establishes the control elevation (Table 4.4).

Chapter 5

Results

The original NSM was developed to provide a better understanding of the predrained hydrology of the Everglades system in south Florida. Planning and restoration initiatives in south Florida have benefited from insights provided by the NSM. The purpose of this study is to use an "NSM-like approach" to gain a better understanding of the natural distribution of flows to the St Lucie Estuary.

An NSM application includes the computer model itself, hydrologic parameters, static data and time series data. If the computer model and hydrologic parameters developed for the original NSM (Version 4.5) are accepted as reasonable, then constructing a natural system model for the St Lucie watershed is a modest effort requiring only static and time series data, which are readily available from previous modeling projects.

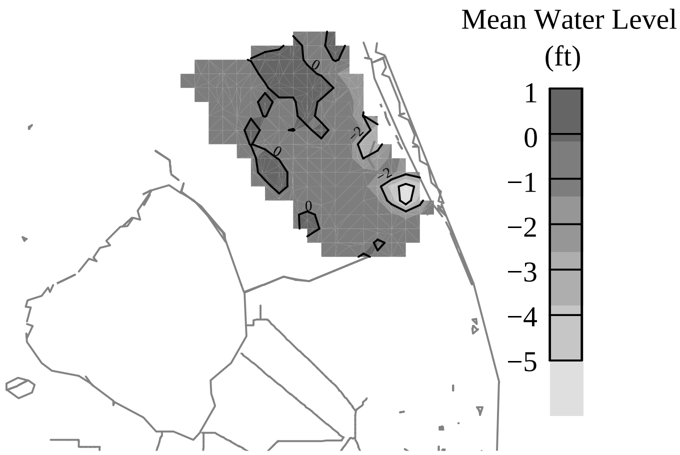
The results of the St Lucie NSM should be viewed as preliminary, and for comparison purposes only. The NSM was developed primarily for an Everglades system. Although similar landscapes exist in both model domains, additional work is required to verify that the hydrologic processes and associated parameters adequately represent in the St Lucie watershed.

5.1 Regional Hydrology

Surface flow in the upper two-thirds of the St Lucie watershed is primarily directed toward the North Fork of the St Lucie River (Figure 5.1). The highest concentration of flow occurs near the western tributary of the North Fork. The lower third of the watershed is generally directed towards the South Fork of the St Lucie River, with much smaller flow volumes

Mean water levels in the St Lucie watershed are generally within 1.0 ft

Figure 5.1: Surface flow vector map.



Notes:
−1965 − 1997 simulation period
− Water levels referenced to land surface elevation
− Contour line interval = 2.0 ft
− Contour shade interval = 1.0 ft
− Canals and levees included for points of reference

Figure 5.2: Mean water level map.

of land surface (Figures 5.2). Mean water levels are generally below land surface in the forested wetlands and above land surface in marshes and wet prairies (see Figure 2.1).

The duration of inudation can be assessed using hydroperiod maps, where hydroperiod is defined as the number of days per calendar year in which the water level in a cell is above land surface. The deep water areas in the wet prairies tend to have longer hydroperiods, ranging between 8 and 11 months (Figure 5.3). Hydroperiods in western to central forested wetlands are shorter, generally ranging between 4 and 7 months. Hydroperiods in areas drained by the St Lucie River and its tributaries are very short, generally less than 4 months.

5.2 Local Hydrology

The depth of water in adjacent cells may differ because of differences in relative topography, vegetation and net rainfall. These localized effects can be minimized by computing the average depth of water for groupings of ad-

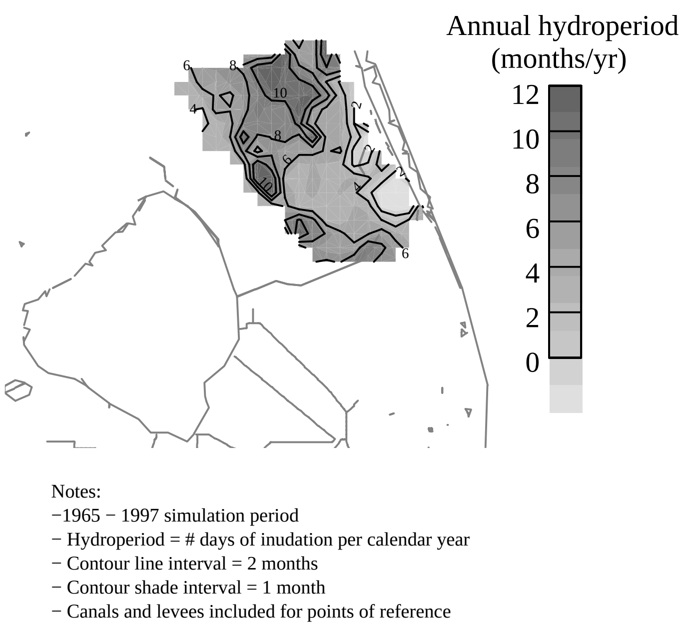


Figure 5.3: Median annual hydroperiod map.

jacent cells. Blocks of at least 3X3 cells were identified in the wet prairie, northeast forested wetland and southwest forested wetland landscapes. Water depth in these blocks is the arithmetic average of the water depth simulated in the individual cells. Daily water depths for each block are sorted by calendar day, ranked in ascending order and presented as percentiles in Figure 5.4. These percentiles summarize the daily distribution of water depths across the 33 year simulation period. For example, the 50th percentile (or median) for January 1 is the water depth wherein 50% of the years report water levels less than this value. The median value is computed for each day of the year, and the results are displayed as the median trace. Traces for the 10th and 90th percentiles are computed in the same manner.

Water levels in each of the landscapes can vary widely throughout the year, dropping as low as 4 ft below land surface in the forested wetlands to as high as 2 ft above land surface in the wet prairie. As previously noted, the wet prairies tend to be wettest of the landscapes. The median water level trace is above land surface for all but four months near the end of the dry season.

5.3 St Lucie Estuary Inflow

The St Lucie River system is represented in the model by four tributaries discharging into the St Lucie Estuary, which in turn discharges to tide. Direct flow into the St Lucie Estuary is estimated by summing the inflows from the North Fork, South Fork, and three smaller tributaries designated as Trib1, Trib2 and Trib3 (see Figure 2.5). The distribution of monthly flow is illustrated in Figure 5.5. Monthly inflow into the St Lucie Estuary (not including direct rainfall and evaporation on the Estuary) ranges from 286 acft/month to 365,000 acft/month, with 90% of the inflows between 2000 and 130,000 acft/month.

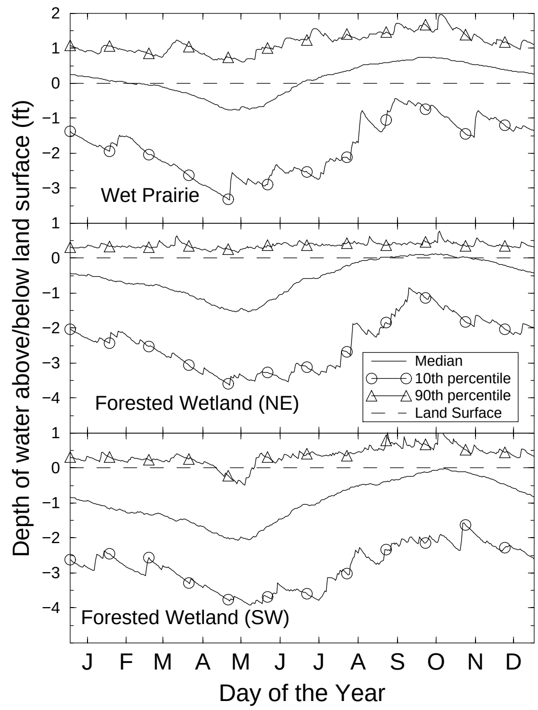


Figure 5.4: Water level percentiles.

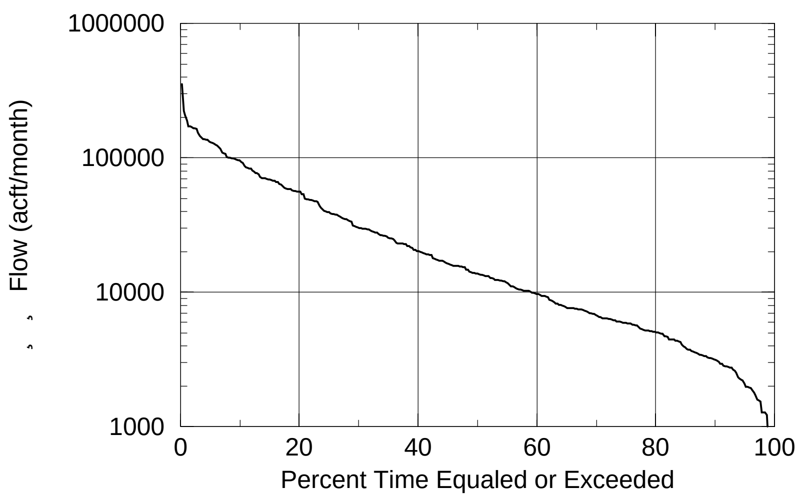


Figure 5.5: Distribution of flow into St Lucie Estuary.

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